RWA

THE RUSSIAN WHEAT APHID

3RD ANNUAL REPORT

DECEMBER 1990

Compiled by Robert L. Burton, ARS Technical Coordinator
Plant Science Research Laboratory
Stillwater, Oklahoma

Agricultural Research Service
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The Russian Wheat Aphid
Third Annual Report of the Agricultural Research Service
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December 1990

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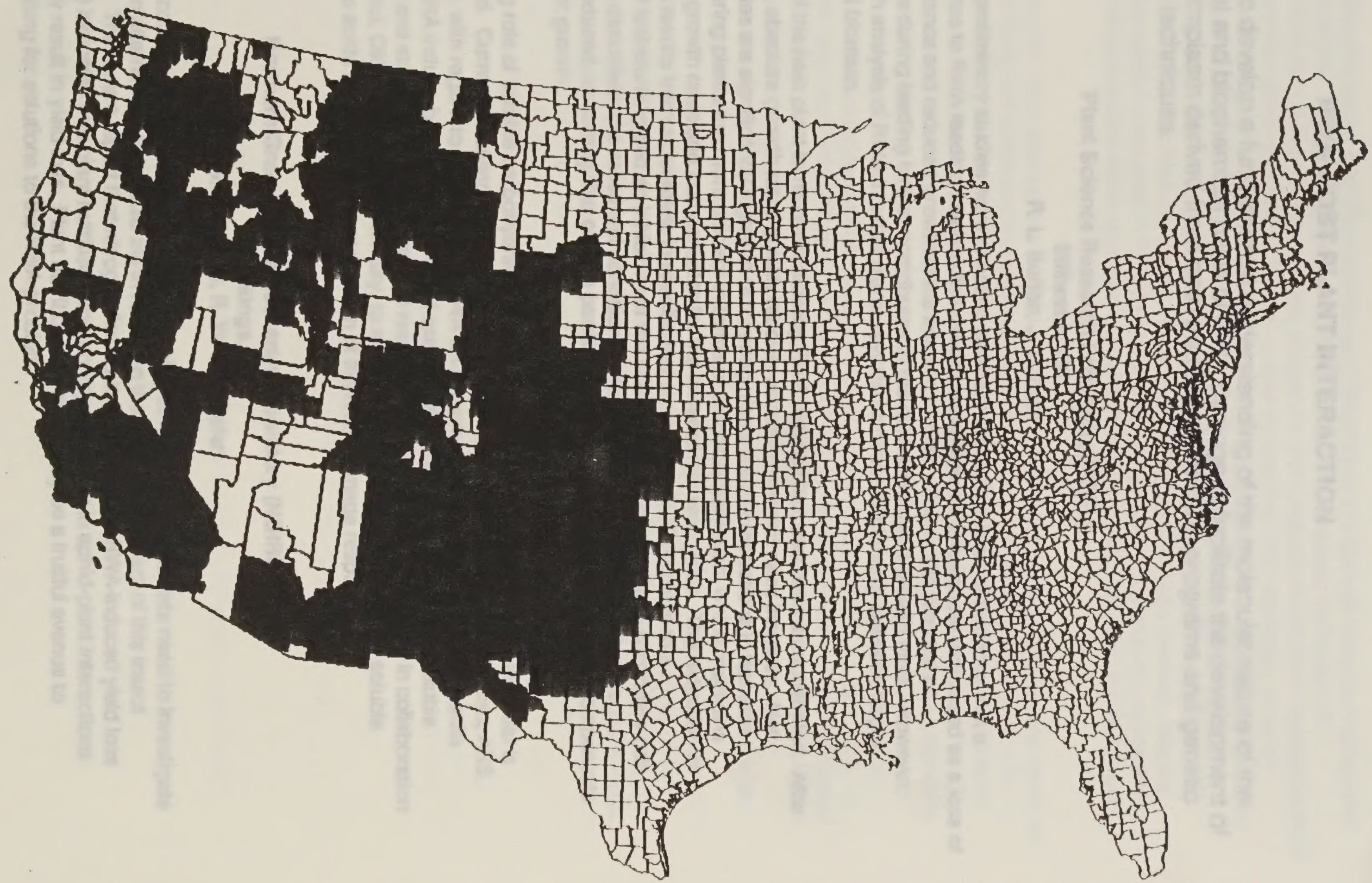
INTRODUCTION

The Russian wheat aphid (RWA) was first detected in the United States in 1986. The new pest insect rapidly migrated to the north and west from where it was first found in the Texas Panhandle until most of the arid/semiarid wheat and barley growing areas of the Great Plains (see map, page 2) were infested. Presently, four and a half years later, the spread has slowed, and it seems to be confined to a 16-state region; very little movement to the east has been detected the past year, and no detections in new states have been made. However, the intensity of the damage by the RWA in the infested states has not decreased. The estimated economic loss for RWA damage and control costs in the United States for wheat and barley has now exceeded one-quarter of a billion dollars. Nor do we expect a decline in losses from this pest; South Africa continues to suffer extensive damage after having had the pest for twice as many years. Fortunately, the technology from our RWA research projects continues to improve, and the new knowledge will help us to eventually reduce the seriousness of this pest. Progress includes the following: new and different natural enemies of RWA continue to be discovered in many regions of the world; new sources of plant resistance continue to be located in germplasm collections; previous sources of resistance continue to be moved toward the development of resistant wheat and barley lines; and the new knowledge of the biology, ecology, and damage aspects of RWA on wheat, barley, and other hosts will give us a better understanding of the pest. This technology will eventually help us to develop successful management systems for the RWA. Conversely, on somewhat of a negative note is the discovery of biotypic variation in world collections of RWA (see Insect Genetics section). The fact that there is a difference in virulence in RWA populations from different countries means that how we view this pest has changed and the research approaches that we take for this pest in the future, particularly on an international scale, will be much more complex than previously expected.

This is the third annual report of research and activities involving the RWA that were performed by the Agricultural Research Service, USDA, in association with the essential cooperation of many other state and federal agencies. The purpose of the report is to outline the activities and accomplishments for the preceding year. The reports are brief due to space limitations. If additional information is needed, the individual scientist can be contacted directly. Names and addresses are located in the Personnel section.

RUSSIAN WHEAT APHID DISTRIBUTION

DECEMBER 1990



RWA-HOST PLANT INTERACTION

Mission: To develop a fundamental understanding of the molecular nature of the physiological and biochemical basis of RWA damage to facilitate the development of resistant germplasm derived from both traditional breeding programs and genetic engineering techniques.

Plant Science Research Laboratory (PSRL)
Stillwater, OK
R. L. Burton, J. D. Burd

The results of preliminary studies have provided several independent lines of evidence that a primary response to RWA feeding involves the development of water imbalances expressed as a loss of turgor maintenance and reduced growth in the infested tissues. Clearly, the removal of photosynthates during feeding further contributes to the diminished plant growth rates. However, detailed growth analysis of RWA-infested plants revealed a direct relationship between turgor levels and total biomass.

The capacity of the host plant to recover following RWA removal has also been demonstrated. After aphid removal, absolute growth rates quickly recover as relative growth rates increase. Net assimilation rates are significantly higher in recovering plants despite reductions in leaf area ratios. Recovering plants are more efficient in terms of carbon assimilation, which maintains higher relative growth rates and compensates for the lowered leaf area ratios. The reduction in leaf area ratios results from a decrease in specific leaf areas. This is attributable to a combination of leaf stunting and an inhibition of the new leaves to unfold. Once secondary cell wall material is deposited, the rolled leaf condition in irreversible. Stem weight ratios are substantially reduced, indicating that carbon partitioning to the crown is decreased to compensate for leaf and root growth.

The intervening role of soluble carbohydrates in osmotic adjustment to water stress in wheat is well established. Currently, research is being conducted in collaboration with S. G. Wellso, ARS, West Lafayette, with regard to the impact of RWA on carbohydrate metabolism. Early results indicate that RWA induce both quantitative and qualitative alterations in constituent soluble carbohydrates and storage fructans. A related research project is being conducted in collaboration with A. C. Guenzi, Oklahoma State University, to evaluate the constituent profiles of soluble free-pool amino acids for further characterization of the RWA damage response.

Northern Grain Insects Research Laboratory (NGIRL)
Brookings, SD
W. E. Riedell, R. W. Kieckhefer

Because RWA continues to be a serious pest of small grains, there is immediate need to investigate crop production alternatives that could aid in reducing the economic impact of this insect (Riedell, 1989). The recent report that nitrogen fertilization ameliorates RWA-induced yield loss (Riedell, 1990a) indicates that plant nutrition plays an important role in aphid-plant interactions which ultimately result in yield loss. Plant nutrition, therefore, may be a fruitful avenue to exploit in searching for solutions to the RWA problem.

Additional studies concerning host plant nutrition and RWA infestation damage have been conducted (Riedell and Kieckhefer, 1991). The objective of these studies was to assess the impact of macronutrient deficiency (nitrogen, phosphorus, potassium, and magnesium) on plant response to RWA damage and upon the aphid population. Results to date indicate that RWA infestation of plants given complete nutrient solution reduced yield approximately 30%. Reductions in yield as caused by RWA infestation in plants grown with specific macronutrient deficiencies were: nitrogen (55%), phosphorus (64%), potassium (52%), and magnesium (69%). All plant macronutrient deficiencies tested reduced the individual RWA dry weight. The number of aphids per plant, however, was not affected. Further studies conducted in the field are needed to document the economic payback and environmental risk associated with a plant-nutrient-based system of plant protection from RWA yield loss.

All of the above yield reductions caused by RWA infestation were accompanied by decreased levels of chlorophyll and increased levels of soluble amino acids. Although correlation analysis has yet to be performed on these data, cursory analysis reveals that chlorophyll and soluble amino acid levels in plant tissue at the time of aphid damage may be related to the amount of grain yield loss. Further studies to investigate these measurements as a way to predict RWA yield loss are planned in cooperation with South Dakota State Agricultural Experiment Station personnel.

Preliminary experiments designed to characterize the biochemical nature of plant-insect interactions have been conducted (Riedell, 1990b). Wheat leaf tissue damaged by aphids contains a 34 kD polypeptide not present in undamaged tissue. This polypeptide may be produced by the plant as a defense mechanism, or may be produced by the aphid and injected into the plant during feeding. Experiments using ^{35}S-methionine and SDS-PAGE autoradiography are in progress in an attempt to determine the biochemical nature of these interactions.

Research is underway to determine the relative importance of aphid population density, length of feeding time, and plant growth stage on ultimate yield loss caused by the stress of aphid feeding. The study is a comparative one, contrasting the mechanisms of yield loss caused by several species of cereal aphid, including RWA. This work is an extension of previous work (Gellner et al., 1990a,b).

HOST PLANT RESISTANCE

Mission: To identify resistance sources, study the nature of this resistance, and cooperate with the Small Grain Germplasm Development program in the development and release of RWA-resistant small grain germplasm.

Plant Science Research Laboratory (PSRL)
Stillwater, OK
J. A. Webster

The Host Plant Resistance and the Small Grain Germplasm Development programs continue to work very closely and continue to have a common primary mission, that is, the release of RWA-resistant wheat and barley germplasm lines to be utilized by public and private plant breeders in developing RWA-resistant cultivars for their specific geographical areas. Observations during a recent trip to the RWA-infested areas of South Africa have underscored the importance of RWA-resistant cultivars in an RWA pest management scheme. It has been stated that in the future, no wheat should be released for the RWA-infested areas of South Africa unless it has RWA resistance. The RWA has been in South Africa since 1978 and obviously remains an extremely serious pest. Based on South Africa's experience, there is no reason to believe that the North American RWA (which has been here since 1986) will "go away" or that its economic impact will decline. Clearly, efforts must continue to scientifically manage this serious new pest.

Mass screening wheat and barley germplasm lines for RWA resistance began soon after the detection of the RWA in 1986, first in growth chamber tests, followed by larger tests in the greenhouse. The tests are conducted with seedlings planted in greenhouse flats and visually scored for RWA damage. A "1" (no damage) to "9" (dead plant) damage rating scale is used to conform with the system used for the GRIN (Germplasm Resource Information Network). The damage rating is published in several progress reports and in Webster et al. (1991), and is based largely on chlorosis of leaf tissue. However, the stunting and turgor components are undoubtedly integrated into the system as the visual readings are made, but a written description of these components has not yet been incorporated into the system. Leaf rolling is also scored on a 1-to-3 basis with "1" representing flat leaves and "3" representing rolled leaves. Most of the germplasm tested has come from the USDA-ARS National Small Grains Collection in Aberdeen, Idaho. Smaller collections from various breeders throughout the world have also been tested. For example, during the 1989-90 year, the following were tested:

Wheat: 3174 PI's from the United States and Canada; 4540 PI's from southwest Asia
Barley: 6458 PI's
Triticale: 731 PI's
Rye: 1238 PI's
Additionally, over 500 miscellaneous PI's, including several cereal-related spcies, were tested

Good levels of resistance have been found in all of the above crops. Information about the resistance in triticale is reported by Webster (1990); in wheat (Porter et al., 1991); and in barley (Webster et al., 1991). Information about RWA resistance in rye is recorded in Host Plant Resistance Germplasm Evaluation reports from this laboratory and will be published in the near future.

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Last year, RWA resistance was reported in several barley lines. Recent tests on the mechanisms of resistance revealed various levels of antibiosis and tolerance in comparison with 'Wintermalt', the susceptible control. For example, in the antibiosis test, an average of 27.3 nymphs per adult were produced on PI 366449 compared with 50.0 on 'Wintermalt'. In the tolerance test, plant growth and leaf area of some of the resistant entries were not affected by the RWA, whereas growth and leaf area of infested 'Wintermalt' plants were only 61% on noninfested 'Wintermalt' plants. Additional information on these resistance mechanisms can be found in Webster et al. (1991). Tests to learn more about the nature of the RWA resistance in barley are in progress.

A series of tritrophic tests in cooperation with the Biological Control program at Stillwater have been completed, and the results will be published soon (Reed et al., 1990). Plant resistance and natural enemies can be a highly effective and compatible combination within an integrated aphid management program, but it is important to consider how the various levels and types of resistance interact with natural enemies when releasing a resistant cultivar.

A cooperative test to compare the reproductive potential of South African RWA's with North American RWA's has been completed. The data have been analyzed and are now being interpreted for publication. The recent visit to South Africa has greatly strengthened our ties with RWA researchers in that country, especially in the exchange and testing of RWA-resistant plant germplasm and natural enemies. In addition, Stillwater continues to cooperate with scientists from several other North American locations in the Uniform RWA Seedling Screening Test. The purpose of this test is to exchange seed of resistant entries and evaluate the performance of these entries under RWA infestations at the different locations.

In the future, we will continue to search for new sources of RWA resistance and study the resistance mechanisms of the new sources. There are still a large number of wheat and barley lines from the National Small Grains Collection that have not been tested. It is important to obtain information about all resistance sources in order to be prepared for the possible occurrence of new biotypes that may in the future overcome some of these resistance sources. In addition, as new sources of resistance are found, we will have to seriously consider the best strategies for deploying these sources to prevent the possible occurrence of biotypes.

SMALL GRAIN GERMPLASM DEVELOPMENT

Mission: To identify, characterize, and introgress genes conferring RWA resistance for small grain germplasm enhancement.

Plant Science Research Laboratory (PSRL)
Stillwater, OK
D. R. Porter, C. A. Baker, D. W. Mornhinweg

Wheat

As a result of the systematic screening effort of the National Small Grains Collection by the Host Plant Resistance program, 417 selections of *Triticum aestivum* exhibiting moderate levels of RWA resistance have been identified to date. These germplasms consist of homogeneous RWA-resistant plant introductions, and RWA-resistant single plant segregants selected from heterogeneous plant introductions. These selections were retested to confirm the level of resistance expressed. Hybridizations were made between several adapted wheat cultivars and 134 selections from the RWA-resistant germplasm. A core collection of 30 RWA-resistant accessions was established based on desirable agronomic traits. Seed reserves of several accessions from this core collection are being increased for use in analysis of genetic control of RWA resistance and for germplasm release. Selected germplasms are undergoing field testing for expression of resistance under controlled artificial RWA infestation conditions (i.e., cage studies).

Barley

Interspecific crosses were made between five RWA-resistant *Hordeum bulbosum* lines and two RWA-susceptible *H. vulgare* malting cultivars. Sixty-eight crosses were made and 557 resultant embryos were rescued. From this process, 97 hybrids were obtained and are now being used in the backcross breeding program. Intraspecific crosses were made between four U.S. malting barleys and three Afghanistan RWA-resistant barley accessions. F_1 progeny from these crosses were increased for evaluation of RWA resistance expression.

Qualitative and quantitative protein differences were detected in a highly resistant Afghanistan barley plant introduction, as compared with a hypersensitive malting barley accession when visualized by silver-staining denatured leaf proteins resolved by isoelectric focusing polyacrylamide gel electrophoresis. Analysis of *in vivo* ^{35}S-methionine labeled protein synthesis before and during RWA attack of these two genotypes revealed several prominent protein products unique to the RWA-resistant barley that were synthesized during RWA attack. The F_2 segregating population derived from hybridizing the resistant and susceptible genotypes will be characterized for protein profiles and corresponding expression of RWA resistance to establish a database for the development of a molecular-marker-assisted RWA resistance selection protocol.

Selected wheat and barley germplasms are undergoing physiological and biochemical characterization of RWA resistance response and the genetic control of those responses.

ALTERNATE HOSTS FOR RUSSIAN WHEAT APHID

Mission: To identify and characterize RWA-resistant germplasm lines that may serve as breeding resources for both cool- and warm-season cereals and turf, range, and conservation grass species.

Plant Science Research Laboratory (PSRL)
Stillwater, OK
S. D. Kindler

The RWA is a serious pest of cultivated barley, *Hordeum vulgare* L., grown where the aphid is endemic. RWA resistance identified in several wild *Hordeum* may provide genetic variation necessary to breed RWA-resistant cultivated barleys. Thus, 1147 accessions (PI's) representing 20 species of wild *Hordeum* obtained from the National Small Grains Collection have been evaluated in the greenhouse for resistance to RWA.

The evaluation criteria were based on plant damage ratings taken around 15 and 25 days after infestation using the standard 1-to-9 scale. Damage ratings of 1 to 3 were considered resistant, ratings of 4 to 6 were considered intermediate resistant, and ratings of 7 to 9 were considered susceptible. Feeding damage ratings taken 25 days after infestation with RWA indicated that 3 accessions had resistance, 42 accessions had intermediate resistance, and the remaining entries were susceptible. Forty-eight accessions were evaluated in greater detail in the greenhouse by measuring plant damage, aphid reproduction, and aphid survival (antibiosis) when confined to the plant for 14 days. The damage rating scores of the 48 accessions ranged from 1.33 to 7.67. There were intra- and interspecific differences among accessions, with the highest levels of resistance in *H. bulbosum* L. and *H. brevisubulatum* (Trin.) Link subsp. *violaceum* Boiss. & Hohen. One accession of *H. bogdani* Wil. had an intermediate level of resistance. Several accessions of *H. bulbosum* and one accession of *H. brevisubulatum* subsp. *violaceum* had low damage ratings, low aphid reproduction, and low leaf-curling ratings compared with other wild *Hordeum* accessions and the cereal checks. Broadening the genetic base of cultivated barley by the introduction of resistant alien genes may provide additional protection from new virulent strains or biotypes of the RWA. Research has been initiated with P. P. Bregitzer, ARS, Aberdeen, and the Germplasm Development program to use "wide crossing" breeding techniques to introduce the RWA resistance identified in wild *Hordeum* into cultivated barley (Bregitzer et al., 1990).

A test has been completed in cooperation with the Biological Control program at Stillwater to determine tritrophic interactions of grasses, RWA, and parasitoids. A manuscript is being prepared, indicating that grasses possessing antibiosis as a resistance mechanism have some detrimental effects on parasitoids and aphids.

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INSECT GENETICS

Mission: To conduct national and worldwide biotypic and genetic studies on the RWA and its parasitoids.

Plant Science Research Laboratory (PSRL)
Stillwater, OK
G. J. Puterka

Biotypic and genetic studies have been initiated to investigate the diversity in populations of RWA and to fingerprint the native and exotic parasitoids of RWA. These studies are being conducted on a national and worldwide scale.

Samples of RWA from Syria, Jordan, France, Turkey, and the Soviet Union have been obtained from T. J. Poprawski, ARS, Behoust, France, via the ARS quarantine facility at BIRL. In addition, RWA samples were obtained from researchers in South Africa, Mexico, Canada, and throughout the United States. A sample of RWA from Chile was collected in November by D. K. Reed, ARS, Stillwater, and K. S. Pike, Washington State University. Over 40 RWA clones were collected from most U.S. states and are currently being maintained for biotypic and genetic studies.

Biotypic variation is of major concern when developing host plant resistance to any insect. To date, biotypic variation has not been recognized in this aphid species, although diffrences in varietal performance between U.S. and South African RWA populations (Butts and Pakendorf, 1984), and differences in varietal susceptibility to different U.S. populations (Bush et al., 1989), have been noted. A study was conducted in collaboration with J. D. Burd, ARS, Stillwater, to determine if biotypic variation exists in the RWA, and to decide what visible criteria should be used to characterize biotypic variation in the RWA. Seven RWA clones from France, Russia, Syria, Turkey, and Jordan were obtained so that virulence and biological traits could be compared with a U.S. isolate. The resistant and susceptible cultivars used to evaluate biotypic variation were PI 366450 (resistant barley), 'Wintermalt' (susceptible barley), PI 386148 and PI 386156 (resistant triticales), 'Beagle 82' (susceptible triticale), PI 372129 and PI 149898 (resistant wheats), and 'TAM W-101' (susceptible wheat). After 17 days postinfestation, plant damage was evaluated using a three-damage-component system that included a 1-to-9 damage rating, 1-to-3 leaf rolling rating, and a 1-to-5 plant stunting rating. Population development of each isolate on each cultivar was expressed as mean total number of aphids per plant 17 days postinfestation. All cultivars, with the exception of PI 386156 and PI 149898, showed differential damage responses to the RWA isolates (Puterka et al., 1990). Six of the eight isolates evaluated had unique biotypic profiles across all cultivars. The USSR biotype was the most virulent and the US isolate the second most virulent among the isolates. Over all cultivars, damage rating was the best criteria for establishing biotypic variation. Plant stunting, leaf rolling, and population development did not always correlate with plant damage. These results indicate that resistance to the RWA will have geographical limits due to variability of RWA virulence. The relationship between RWA biotypes and plant damage ratings was also reflected by the quantitative plant parameters (plant biomass partitioning). However, biomass partitioning could identify intermediate plant damage responses that were not detected using damage ratings (Burd et al., 1990).

The genetics of RWA biotypes are being characterized by electrophoresis of enzymes, 2-D electrophoresis of total aphid proteins, and sequencing of genes in both the nuclear and mitochondrial genomes to determine the degree of relatedness between the biotypes, and, possibly, the origin of the U.S. RWA population. This information would aid in the search for sources of RWA resistance and more effective natural enemies. Fifteen of 26 enzymes assayed were suitable for further analysis. Four of 15 enzyme loci investigated showed polymorphisms confirming that some biotypes are genetically distinct. A detailed enzyme analysis is currently being conducted on aphid populations within countries (France, Canada, South Africa, United States) to determine if the polymorphic enzyme loci are unique alleles or are fixed alleles within countries and could serve as geographic race (biotype) markers.

In a collaborative effort with D. R. Porter, Germplasm Development program, total proteins of the RWA biotypes and U.S. isolates are being mapped. Differences between biotype protein profiles have been detected in acidic protein complexes between 30 and 50 KD. This technique looks promising for fingerprinting and determining the genetic diversity of RWA biotypes.

The mitochondrial genome of the RWA biotypes is being studied in conjunction with T. O. Powers, University of Nebraska. PCR (polymerase chain reaction) amplified regions of the mitochondrial DNA are being sequenced to determine the degree of relatedness between the biotypes, and identify which regions within the genome are conserved or variable. Variable regions of the mtDNA will be useful in constructing race- (biotype) or genotype-specific DNA probes. The regions investigated thus far have found no sequence differences between RWA biotypes from the worldwide collection. Other regions are currently being investigated in an effort to find genetic variability.

The rDNA cistron of the RWA is being characterized in collaboration with W. C. Black IV, Kansas State University, to be used for the same purpose as the mtDNA. PCR is also being utilized to amplify genes and spacer regions in the rDNA cistron. These amplified genes are currently being cloned so that they can be sequenced.

Electrophoretic fingerprinting of native and exotic parasitoids is being led by W. W. M. Steiner, ARS, Columbia, in cooperation with G. J. Puterka and D. K. Reed, ARS, Stillwater. The fingerprinting primarily involves exotic *Diaeretiella rapae* (McIntosh) and *Aphidius matricariae* Haliday compared with indigenous *Lysiphlebus testaceipes* Cresson and *Aphelinus varipes* Forester. Enzyme fingerprinting has been successful in documenting the establishment of *A. matricariae* at Goodwell, OK (G. J. Puterka and D. K. Reed, unpublished data). A recent project has also been initiated in cooperation with R. L. Roehrdanz, ARS, Fargo, to develop race-specific mtDNA probes for exotic parasitoids.

The various genetic techniques that we are using to study the RWA will provide baseline genetic information and bring a better understanding of the population structure and diversity of this important pest.

Biological Control of Insects Research Laboratory (BCIRL)
Columbia, MO
W. W. M. Steiner

Genetic investigation of parasites and predators of RWA is continuing. This past year, surveys of laboratory strains available at the PSRL, Stillwater, were completed, and surveys of release strains of imported coccinellids available at the APHIS Biological Control of Insects Laboratory, Niles, MI, were begun. In addition, ARS-supported TDY research was initiated to explore the genetic backgrounds of predators and parasites in their endemic home countries in Western Europe and the Mediterranean Basin. The growing data file is still under analysis, but the salient features to date have some significance for release personnel in the field. The data are based on electrophoretic gene markers, the genetic bases for which have been established in the braconid parasite *Microplitis croceipes*, host-specific to moths of the genus *Heliothis*, and the coccinellid *Coleomagilla maculata*, a generalist endemic to mid-America. The techiques, equipment, and methods are described by Steiner and Joslyn (1979) and Steiner (1988) and have been used with only slight modification.

In the following studies, the isozymes or electomorphs are numbered, with "allele 5" being the most commonly occurring isozyme in the control organism, which in this case was *Aphidius matricariae*. Electromorphs that migrate faster (anodally) in the electric field of the gel are assigned a lower number (1-4) and those that migrate slower (cathodally) are assigned a higher number (6-9). Species with the same allele designation thus have the same electromorph. Thus allele L.T. PGI 3 is faster than allele A.M. PGI 5, while D.R. PGI 6 is slower. All allele designations are relative. Details and photographs will be forthcoming in a series of publications currently being prepared.

<u>Genetic Studies of Parasites of *D. noxia*</u>
(with D.K. Reed, G.J. Puterka, R.L. Burton, PSRL; K.R. Hopper, EPL; P.M. Marsh, SEL)

These studies were initiated to genetically characterize or "fingerprint" potential release strains of specific parasites. In this manner, it was hoped that the fate of released individuals in the natural populations could be traced in an attempt to determine which genetic types had higher fitness values, and to determine how fast a strain was spreading in nature following a release. Over 50 individuals were sampled for each isozyme gene locus.

The resulting data indicate that we may discern which isozyme genes are segregating for two or more alleles, even though some lines are fixed homozygous. This is because the fixation process, due to random genetic drift and "founding" effects, can result in alternative alleles being fixed at random in different lines. Since we don't know if different strains of a species from different countries will cross to produce fertile hybrids, we can't say if these genetic differences can be used as markers to follow movement and to determine strain-dependent efficiency in the field.

Finally, the TDY work overseas was undertaken to determine the extent of loss of genetic variation that occurred during the colonization, clearing, and shipping phases of a release project. Not enough beneficial wasps were collected for this portion of the study, but enough were collected to give clues as to the occurrence and possible role of genotype-dependent host specificity.

In these studies, the aphid hosts *Rhopalosiphum padi* and *Diuraphis noxia* were collected on long-eared wheat in a single field near Grabel, France, in late June 1990, with the mummies of both species often coming from the same plant stem. The emerging parasites were identified as *Aphelinus* spp. by P. M. Marsh and were electrophoretically verified as to species with laboratory-reared controls of *A. asychis* and *A. varipes*. Over 50% of the *R. padi* mummies with their parasite were hyperparasitized with *Alloxysta* sp.

What the limited data suggest is that in areas where host competition exists, *A. asychis* prefers to oviposit in *D. noxia*. While *A. varipes* seems to prefer *R. padi* as a host, one (9.1%) was reared from *D. noxia*. A Contingency-Chi square analysis, even with small numbers, supports this strong aphid-host dependency. This type of competition deserves some closer scrutiny by insect ecologists since it has serious implications for release programs. We don't know how season or other features affect this relationship.

Genetic Studies of Predators of *D. noxia*
(with R. L. Flanders, APHIS Niles; T. J. Poprawski, PPRL)

In these studies, we were interested in tracing the survivorship and movement of specific genotypes, just as in the parasites. But because the predators under consideration are generalist feeders, we could also determine if certain genotypes were "niche-specific" in terms of host selection. In addition, the TDY investigation in Europe was undertaken in order to determine the extent of genetic loss that occurred during the colonization, clearing, and shipping phases of a release project.

From the great amount of genetic information we have generated to date on this project, the following observations are relevant. First, there is a tremendous amount of electrophoretic genetic variability in coccinellids, with 50% or more of loci segregating for multiple alleles in many species in their endemic ranges. However, within 3-4 generations of being colonized, cleared of parasites and pathogens, and moved to the United States for rearing and release by APHIS, a great loss of genetic variation occurs, as much as 75% in *Hippodamia variegata* and *Coccinella septempunctata*, and 60% in *Propylea quatuordecimpunctata*. Additionally, we found stong genetic differences between *C. septempunctata* from Kirghizia and all other sites (15 of 17 loci had fixed genetic differences), or between *H. tredecimpunctata* and *P. quatuordecimpunctata* from Moldavia and all other sites (5 of 18 and 3 of 21 loci show fixed gene differences, respectively). Generally, when insect species show more than a 10% difference in their genomic content, questions concerned with taxonomy and systematics can be raised. Generally speaking, the Canadian population of *C. septempunctata* that we analyzed was genetically very similar to the "European" type exemplified by the French and Greek samples.

European Parasite Laboratory (EPL)
Behoust, France
K. R. Hopper

Genetic Variation in Traits Affecting Success of Biological Control

A laboratory experiment showed that the heritability of the search rate of *Aphelinus asychis*, a parasitoid of *Diuraphis noxia*, was not significantly different than zero (parent-offspring regression, $P>0.9$). This result supports the idea that genetic variation is low for attributes likely to affect success of parasitoids in biological control. However, a larger sample of parent-offspring pairs is needed, and it is likely that the bioassay of search rate was not precise enough to be conclusive. An improved bioassay for parasitoid search rate was developed by measuring functional response (numbers parasitized vs. host density) and age-specific fecundity in the laboratory. The heritability experiments will be repeated with this improved bioassay.

Effect of Mass Rearing vs. Isofemale Lines on Genetic Change under Laboratory Rearing and on Parasitoid Establishment

Fourteen isofemale lines (with 5 sublines/line) and a mass-rearing culture of *Aphelinus asychis* from *Diuraphis noxia* collected near Antibes in 1989 have been maintained for the last year. A field test in cooperation with R. T. Roush, Cornell University, on the probability of establishment of releases from these two culture methods was attempted, but the aphid populations in the release area were too low to measure differences in establishment or parasitism. This experiment will be repeated next year in an area with outbreak densities of *D. noxia*. Twenty-nine isofemale lines (with 5 sublines/line) and a mass-rearing culture of *A. varipes* were set up from collections of *D. noxia* in the Montpellier, France, region. These will be used for experiments on the heritability of attributes likely to affect success in biological control and on changes under laboratory rearing.

SIMULATION MODELING

Mission: To develop quantitative technology for incorporation into management decision support systems.

Plant Science Research Laboratory (PSRL)
Stillwater, OK
N. C. Elliott

A simulation model of the population dynamics of the RWA was expanded to include new biological information. Specifically, the effects on RWA population dynamics of intraspecific competition for food and wheat plant developmental stage were studied, quantified, and incorporated in the model. A validation data set was obtained in cooperation with G. L. Hein, University of Nebraska, Scotts Bluff. The model is being tested against the validation data to determine how well it describes essential features of RWA population dynamics. Plans for 1990-1991 include expanding the model to include more information on RWA biology and ecology as it becomes available, interfacing the model with models of the population dynamics of other cereal aphids and a wheat plant growth model. Models of the population dynamics of other economically important cereal aphids are currently being constructed for the above mentioned purpose. Additional validation studies will also be conducted.

BIOSYSTEMATICS

Mission: To provide identifications and verifications for RWA and its natural enemies.

Systematic Entomology Laboratory (SEL)
Beltsville, MD
M. B. Stoetzel

During FY90, Dr. Stoetzel provided identifications and verifications for *Diuraphis noxia* (Mordvilko). There is a continuing need for voucher specimens to be submitted to the SEL as researchers search for parasites and predators of the RWA.

From 11 to 16 June, Dr. Stoetzel worked at the Agriculture Research Station in Summerland, British Columbia, Canada. Summerland is the type locality for *D. nodulus* (Richards), a species closely related to *D. noxia*. Unfortunately, the aphid was not found on this trip. The whole Okanagan Valley had a very cool, rainy spring.

Dr. Stoetzel also has been cooperating with F. B. Peairs, W. L. Meyers, and R. W. Hammon, Colorado State University. Mr. Hammon, an extension agent in Grand Junction, succeeded in collecting *D. tritici* (Gillette) and a species of *Diuraphis* that is probably *D. nodulus*. Attempts were made to establish laboratory colonies of both species. From 16 to 21 July, Dr. Stoetzel worked at Fort Collins where she sampled and studied the laboratory colonies of *D. noxia*. Dr. Stoetzel also traveled to Meeker, where she met with Mr. Hammon; they succeeded in collecting samples of the species of *Diuraphis* that are probably *D. nodulus*. There have been problems transplanting mountain bromegrass from the field into pots in the laboratory. However, pots containing young shoots of mountain bromegrass started from seed were supporting a sparce population of this aphid at Fort Collins. Dr. Stoetzel transplanted a few clumps of mature mountain bromegrass; at last report those plants were doing well. Unfortunately, the laboratory colony of *D. tritici* was lost.

Dr. Stoetzel was again in Summerland, British Columbia, 3-8 September, to search for aphids on grasses. *D. nodulus* is known only from its original collection of 6 September 1955. On September 5th, she found one clump of downy bromegrass (*Bromus tectorum* L.) with a fairly large population of *D. nodulus*. She collected a few apterae, and the clump was hand carried to Cho-Kai Chan, Agriculture Canada, Vancouver, B.C., to establish a laboratory colony for further rearing. On the morning of September 7th, Dr. Stoetzel found additional apterae and nymphs on young shoots of downy bromegrass. Several clumps of grass infested with aphids were forwarded to Mr. Chan, but no alates were reared. In the spring of 1991, Mr. Chan will try to recollect this aphid.

Dr. Stoetzel continues to lack the technical support needed to prepare and mount aphids on slides so that they can be studied; however, she expects to complete her revision of the genus *Diuraphis* in FY91.

BIOLOGICAL CONTROL

Mission: To collect, study, and release exotic natural enemies of the RWA into the RWA-infested grain growing regions of the United States as a control strategy.

Plant Science Research Laboratory (PSRL)
Stillwater, OK
D. K. Reed, N. C. Elliott

During the past year, rearing techniques have been refined so that this laboratory can maintain study cultures of all exotic parasitoids as they are collected and, additionally, maintain large colonies for release and/or shipment to cooperators. Exotic parasitoids collected by personnel from the EPL and state universities currently being cultured include *Diaeretiella rapae* from USSR, Syria, Pakistan, and France; *Aphidius matricariae* from USSR, Greece, Turkey, and Iraq; *A. colmani* from Czechoslovakia and Pakistan; *A. picipes* from Czechoslovakia; and *A. colmani*, *Ephedrus plagiator*, and an unidentified *Aphidius* species, all from South America. A colony of the greenbug parasitoid *Lysiphlebus testaceipes* is also being maintained for host preference and other studies.

Studies have continued on biological properties of parasitoids, such as host preference, searching rate, and host-parasitoid relations. Studies have been completed on tritrophic relationships between *D. rapae* and RWA on small grains (Reed et al., 1990) and also on grasses. In both systems, parasitoids resulted in substantial decreases in aphid populations, and antibiotic plant entries, whether small grains or grasses, had great effect on both the aphid and the parasitoids reared on these aphids. On the other hand, plant entries that were tolerant to RWA exhibited no detrimental effects to either the aphid or parasitoid, and the natural enemy was successful in lowering aphid populations.

A new building is presently being constructed to house the Biological Control group at Stillwater. This building will consist of office, laboratory, rearing, and work space to facilitate rearing and research projects previously hampered by lack of adequate research facilities. Anticipated completion date is February 1991.

Work is continuing on genetic marking of exotic parasitoids in order to determine the origin of collections within release areas, in cooperation with the Insect Genetics program. A release was made of *D. rapae* and *A. matricariae* in the Oklahoma Panhandle during the spring of 1990. These parasitoids were identifiable due to genetic fingerprints. Two specimens of *A. matricariae* were recovered and identified as progeny of the parasitoids previously released. Cultures of all available Aphididae are being maintained under cryogenic conditions for future research.

Since the countries of Chile and Argentina are reported to have excellent biological control of small grain aphids, and since the RWA is present in Chile, a collecting and fact-finding trip was made by D. K. Reed and K. S. Pike, Washington State University, to these countries and also to Brazil. Almost 2000 specimens of parasitoids were shipped to BIRL and Texas A&M University. These included *Aphelinus* sp., *Aphidius* sp., *Praon* sp., and *Ephedrus* sp. Four species of coccinellids were shipped to BIRL (about 300 specimens). About 100 fungal-infected aphids were sent to PPRL for identification by R. A. Humber. As expected, the predominant species was *Pandora neoaphidis*. Other specimens were identified as *Entomophthora planchoniana* (*Chromaphis*) and *Zoophthora occidentalis*.

Work on predators of the RWA is progressing. Several predaceous coccinellids were compared in field cage studies to determine if the approach was useful for evaluating their predatory potential on aphids in small grain fields. The field cage method proved adequate to distinguish among predators in terms of prey population suppression and the timing of oviposition. Basic studies are planned using one or two of the coccinellids collected in South America that are not now colonized in the United States.

Field studies of the overwintering ability of several RWA parasitoids along a north-south gradient in the Great Plains region are currently being conducted. The study is a cooperative venture between ARS (D. K. Reed, N. C. Elliott, R. W. Kieckhefer), Kansas State University (J. R. Nechols), and the University of Nebraska (G. L. Hein). APHIS, Mission, TX, has been supplying some of the parasitoids required for the studies.

Northern Grain Insects Research Laboratory (NGIRL)
Brookings, SD
N. C. Elliott, R. W. Kieckhefer

A three-year study to determine the influence of exotic predators on native predator communities will be completed this year. The study was conducted cooperatively with W. C. Kauffman, APHIS, Otis AFB, MA. Preliminary results suggest that *Coccinella septempunctata*, a European coccinellid introduced into the United States for aphid control, may have partially displaced several native species from small grain fields and fields of at least two other crops. The net effect of the modified coccinellid species assemblage on the biological control of aphids in the crops is being evaluated.

Efficient population estimation procedures for coccinellid predators of the RWA also were developed cooperatively with W. C. Kauffman, APHIS.

Analysis of 13 years of census data from field populations of aphid predators occurring in field crops in South Dakota yielded information on species composition of predator populations, levels of abundance, and seasonal life history. In small grains, two species of ladybeetle, *Hippodamia convergens* and *H. tredecimpunctata tibialis*, were consistently dominant in an assemblage of at least six species of ladybeetles. Composition of assemblages was quite consistent over the years and at sampling sites, but abundance of species varied widely over the years. A technique was proposed for evaluating the effect of introduced predators on species assemblages of the indigenous coccinellid species (Elliott and Kieckhefer, 1990).

Plant Protection Research Laboratory
Ithaca, NY
R. A. Humber, S. Wraight, T. J. Poprawski

Wheat and barley fields in the vicinity of Fort Collins, CO, were monitored during June and July of 1990 to characterize their natural populations of aphids and associated pathogens, parasites, and predators. Although processing of the samples is still underway, preliminary results indicate that at least three fungal pathogens are active in the region against four aphid hosts; viz., *Pandora neoaphidis*, *Entomophthora chromaphidis*, and *Conidiobolus obscurus* against *Diuraphis noxia*, *Rhopalosiphum padi*, *R. maidis*, and *Schizaphis graminum*.

Data from irrigated and nonirrigated sites suggest that moisture is the dominant limiting factor in the activity of these pathogens in Colorado wheat culture (primarily a dryland production system). Rainfall was minimal during June, and the level of fungal infection in nonirrigated sites with RWA densities of greater than 5 per tiller was less than 1%. At the same time, infection (predominantly of *E. chromaphidis*) reached a maximum of 14% in an irrigated field with only 2.4 RWA per tiller. The highest level of fungus activity was observed near the end of the growing season in an irrigated field of spring barley; infection peaked at 50-60% between 18 and 24 July. The dominant pathogen in this field was *P. neoaphidis*, and the observed epizootic was likely stimulated by the high density of the host population (65 RWA per tiller). Concomitant sampling of a similarly heavily infested nonirrigated barley field revealed only 3% infection. These observations suggest that release or application of fungal pathogens for RWA control would be most effective in irrigated systems (although dryland cultures could also be targeted during periods of above normal precipitation).

Host density is another determinant variable in the development of fungal epizootics. Disease outbreaks in high density aphid populations at the end of crop seasons are well documented. In many agricultural systems, these late epizootics are believed to be of little economic importance since the crop is already severely damaged by the time the aphid population is affected. However, throughout much of the western and midwestern United States, small grains are comonly planted in the fall, and fungal epizootics that occur during July contribute to a reduction in the oversummering aphid population, which possibly impacts the level of infestation of the fall crop. Unfortunately, after the winter, the endemic fungal pathogens typically do not become highly active again until June or July, and if heavy spring aphid migrations occur, even irrigated fields can be reinfested and severely damaged before these fungi can exert any useful level of control.

In view of this situation, we propose to identify cold-tolerant strains of exotic or native fungi with high epizootic potential, introduce them into migrating aphid populations during early spring via intensive point inoculations, and then determine if they are dispersed along with their hosts and become active earlier in the season than the indigenous pathogens. An alternative approach will be to broadcast low doses of fungal material (in the form of granular, dry-formulated mycelium) over large areas, the mycelium particles substituting for infected dispersing winged aphids.

The most common parasitoids collected from our 1990 study sites were *Diaeretiella* and *Aphelinus* spp. Incidence of these parasites was extremely low (generally less than 1%) until late in the season, and even then did not exceed 10%. Parasitism levels were highest in the nonirrigated fields. Syrphid fly larvae appeared to be the most important predators of aphids in the irrigated fields, while in the drier fields, adult and larval coccinellid beetles predominated.

R. A. Humber provided fungal cultures and information about the biology and handling of fungal pathogens of RWA and other cereal aphids to several laboratories throughout the United States and Canada. The most commonly observed fungal pathogen of RWA in North America and elsewhere continue to be the entomophthoralean fungus *Pandora neoaphidis* (Remaudière & Hennebert) Humber (= *Erynia neoaphidis* Remaudière & Hennebert) with a minor incidence of *Conidiobolus obscurus* (Hall & Dunn) Remaudière & Keller. Fungal strains isolated from European collections of *D. noxia* will be sent from EPL during the early part of FY91 for accession and storage in the ARSEF culture collection maintained at Ithaca.

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European Parasite Laboratory
Behoust, France

K. R. Hopper, T. J. Poprawski, F. Gruber

Foreign Exploration

Exploration for biological control agents for RWA was conducted by the EPL in cooperation with scientists of the All Union Research Institute of Biological Methods in Agriculture (Kishinev, Moldavian SSR), the Kirghiz Agrochemical Consortium (Frunze, Kirghiz SSR), the Central Asia Research Institute for Plant Protection (Tashkent, Uzbek SSR), the French National Institute for Agricultural Research, the National School of Agronomy (Montpellier, France), the ARS Biological Control Laboratory (Columbia, MO), the ARS Biological Control of Weeds Laboratory (Thessaloniki Field Station, Greece), and the Bornova University (Izmir, Turkey).

Diuraphis noxia, its parasites, predators, and fungal pathogens were recovered from several sites in Greece, Turkey, Kirghizia, Uzbekistan, and southern France. The biocontrol agents were multiplied at the EPL and shipped to cooperators in the United States. Details on the results of the surveys are given in the trip reports prepared by the explorers and are also documented in the shipment records of the EPL. Damage symptoms in fields of wheat attributable to RWA were observed in western France (Brittany and Normandy), but the aphid was not recovered from these fields. RWA was not found during a survey in northern France and southwestern Germany. Over 75% of the 850 *Adonia* and *Propylea* adults collected from RWA-infested barley in the vicinity of Tashkent died from natural fungal infection (*Beauveria bassiana*) while being quarantined.

F. Gruber became ill during his first trip to USSR during May and was unable to return to work until late July. At that time it was not appropriate to return to USSR (Kirghizia) due to the unrest in this area. In fact, no parasitoids were collected during this year from RWA in USSR. Approximately 100 of one species of *Aphidius* sp. collected in the southeast of France from *Bracycorynella asparagi* on *Asparagus* and successfully exposed to RWA at the EPL will be shipped. Some predators were shipped from Kirghizia by T. J. Poprawski and some others collected from *Brachycorynella asparagi* in September in the southeast of France.

Distribution of *D. noxia* and its Parasites and Pathogens in Southern France

In a survey of 32 wheat and barley fields in mid-May (crops in boot to inflorescence stage) in the region of Montpellier, 19 fields (60%) were found to have colonies of *D. noxia*. Barley fields were more frequently infested (6/6 fields) than wheat fields (13/26 fields) (Chi-square test, $P<0.05$). Furthermore, barley fields tended to be more heavily infested than infested wheat fields. There was a tendency for the wheat variety 'Arcour' to be more frequently infested (5/6 fields) than the wheat variety 'Ardente' (1/5 fields), but data were not available for enough fields to be conclusive. No fields were treated with insecticides so this factor could not have affected *D. noxia* distribution. Previous crop, field size, and amount of nitrogen fertilizer had no effect on whether or not fields were infested.

Mean parasitism estimated by rearing *D. noxia* collected in barley and wheat fields in mid-May was 4%. The main species of parasitoid was *Aphelinus varipes*, but *Aphelinus asychis* and *Diaeretiella rapae* were also present. The fungal pathogens *Pandora neoaphidis* and *Erynia radicans* were found on *D. noxia* in some fields, particularly those that had been sprinkler irrigated. These parasites and pathogens are being shipped to the United States for release in the field by cooperators.

After harvest (mid- to late-June), *D. noxia* was found on wild grass species in and around previously infested fields. After these grasses had dried out (late July and August), *D. noxia* was found on the cover grass, *Bromus catharticus*, in irrigated orchards. Rain in late August and early September induced volunteer wheat and barley, and by the first week in October, *D. noxia* had recolonized barley and wheat in 5 out of 6 fields that had abundant volunteer plants. Field surveys will be continued at monthly intervals, and trapping of alate *D. noxia* in newly planted wheat and barley fields will be initiated.

Analysis of Annual Variation in *D. noxia* Abundance in Southern France

Data were obtained from F. Leclant (Ecole Nationale Superieure Agronomique de Montpellier, France) on trap captures of *D. noxia* in a Rothamsted, 12-meter, suction trap operated in Montepellier since 1979. An analysis was done of the relation between annual trap captures and rainfall, temperature, and wind data from the French National Weather Service. There was a weak but significant negative correlation between winter rainfall (September-April) and the trap catch in the following year, suggesting that winter rainfall reduced aphid density. Preliminary analysis of low rainfall years suggests density dependence of the growth of the *D. noxia* from one year to the next.

Impact of Natural Enemies of *D. noxia* Abundance in Southern France

A field exclosure experiment in Montpellier showed that natural enemies significantly reduced density of *D. noxia*. In this experiment, individual wheat plants in the boot stage were artificially infested with five *D. noxia* (apterous 4th instar or adult) after the plants had been sprayed with insecticide to remove all insects. The plants were then either covered with a closed cage to completely exclude natural enemies, covered with an open cage to allow access by natural enemies and to control for the effect of the cage on microclimate, or left uncaged. The treatments were arranged in a randomized complete-block design (72 replicates), and 12 blocks were sampled destructively for aphids at 1- to 2-week intervals for 7 weeks after infestation. Mean density over the duration of the experiment was much higher on closed-cage plants (24.1% 7.9 per plant, mean% SE) than on open cage (5.9% 1.6) and uncaged plants (1.3% 0.4). The trajectories of *D. noxia* densities for each show that the rate of population growth was much higher on closed-cage plants than on open-cage and uncaged plants. That this growth was not from restricted immigation is shown by lack of alate forms during week 4 when the upsurge in aphid density occurred on closed-cage plants and by the similarity of wing-form frequencies on closed-cage and open-cage plants. Densities of coccinellids and syrphids appeared high in this field, but the levels of parasitism and pathogen infection of *D. noxia* were low, suggesting that predation may have been the predominant cause of mortality in this experiment. The experiment will be repeated in 1991 with an earliler start and quantitative sampling of predators.

Other Activities

The influence of geographic origin, food crop, and temperature on the biology of RWA has been studied in the laboratory. Data analysis has been completed, and a manuscript is being drafted.

Studies on the interaction between fungal pathogens and parasitoids of RWA have been initiated recently. Concomitant studies using *Schizaphis graminum* as hosts are in progress in Ithaca.

Beneficial Insects Research Laboratory (BIRL)
Newark, DE
L. R. Ertle, P. W. Schaefer

Quarantine Handling of Natural Enemies of RWA

A total of 47 consignments of natural enemies of RWA were received at BIRL in 1990. Of the 2125 specimens, 1616 were received alive. All material was collected in the USSR (Uzbekistan, Kirghizia, or Ukraine), Brazil (Rio Grande de Sul), Chile (localities between La Cruz and Santiago), Argentina (Rafaela), and France. Thirty-six of the consignments were various lady beetles (Coleoptera: Coccinellidae) collected while feeding on or in the vicinity of field populations of RWA. Nine identified species of aphidophagous Coccinellidae were received (four additional cultures have pending identifications): *Coccinella septempunctata* L., *Hippodamia tredecimpunctata* (L.), *H. variegata* (L.), *Semiadalia undecimnotata* (Schneider), *Adalia bipunctata* (L.), *Propylea quatuordecimpunctata* (L.), *Coccinula quatuordecimpustulata* (L.), *Oenopia* (=*Synharmonia*) *conglobata* (L.), and *Eriopis connexa* (Germar). In addition, several braconid parasites were received: *Aphidius* sp., *A. colemani* Viereck, *A. matricariae* Haliday, *Praon* sp., *P. gallicum* Stary, and *Diaeretiella rapae* (McIntosh). However, up to 90% of the South American samples were hyperparasitized by *Alloxysta* sp. (Hymenoptera: Charipidae).

Thirty-four shipments of beneficial parasites and predators comprising 12 different species were released from quarantine. Almost all of the aphidophagous coccinellid species were sent to R. L. Flanders, APHIS, Niles, for additional evaluation and culture (22 shipments, about 1800 specimens). Eleven shipments (311 specimens) of beneficial parasites comprising five different specimens were shipped to D. K. Reed, PSRL, for study.

Quarantine Evaluation of Natural Enemies of RWA

Many of the incoming shipments involved species received previously: *Coccinella septempunctata, Hippodamia variegata, H. tredecimpunctata*, and *Propylea quatuordecimpunctata*. Other shipments contained some new and different material. One such species, *Adalia bipunctata*, was obtained from Uzbekistan, USSR, in two strikingly different color morphs. Another from the same location included *Oenopia conglobata* (previously referred to as "Brown/Mottled White"), and *Coccinula quatuordecimpustulata* were found to be mixed with *P. quatuordecimpunctata*. A shipment from Santa Fe Province, Argentina, has provided *Coccinella ancoralis, Eriopis connexa*, and *Coleomagilla quadrifasciata*. Similarly, a shipment from Chile has provided three as yet unidentified species.

During 1990, our successful coccinellid rearings (all on pea aphid) have provided the following species for propagation and further study: *Adalia bipunctata* (L.) (origin: Uzbek, USSR); *Coccinella septempunctata* (Khafsa, Syria; Uzbek, USSR); *Hippodamia variegata* (Goeze) (Quebec, Canada; Meknes, Morocco); and *Oenopia conglobata* (L.) (Uzbek, USSR). As of year end, we are rearing 19 cultures, including *E. connexa* and *C. quadrifasciata* from Argentina which are the only two with confirmed identifications. Other cultures have come from Germany (2 cultures), USSR (10 cultures); Argentina (1 culture in addition to the above mentioned 2), and Chile (3 cultures). Species currently reared include *Semiadalia undecimnotata* (Schneider), *Scymnus frontalis* (F.), and all species mentioned above except for *Coccinula quatuordecimpustulata*. Some incoming shipments contained non-aphidophagous species, which were not reared but simply preserved for museum specimens, including *Tytthaspis sedecimpunctata* (L.), a fungus feeder, and the mite predators *Hyperaspis* spp.

The introduction of material from the Steppe regions of the USSR is particularly noteworthy, because this area is climatically and ecologically similar to the Prairie regions of the United States and Canada. where the RWA is now found.

PERSONNEL

During 1990, several changes in personnel occurred due to retirements and reassignments. Dr. R. F. Moore retired from his position as Research Leader of the European Parasite Laboratory, and T. J. Poprawski was reassigned from EPL to PPRL at Ithaca. K. R. Hopper is now the principal scientist at EPL. At Stillwater, D. R. Porter has become established as the principal scientist on the Germplasm Development program after being hired at the end of 1989. N. C. Elliott was relocated from NGIRL at Brookings to PSRL at Stillwater where he continues his Simulation Modeling program and cooperative projects in Biological Control.

RWA Project	Personnel
RWA/Host Plant Interaction	Stillwater, OK Robert Burton, Research Entomologist John Burd, Biological Technician Brookings, SD Robert Kieckhefer, Research Entomologist Walter Riedell, Research Plant Physiologist
Host Plant Resistance	Stillwater, OK James Webster, Research Entomologist Keith Mirkes, Agricultural Research Technician Kathy Crump, Senior Agriculturalist
Germplasm Development	Stillwater, OK David Porter, Research Geneticist Cheryl Baker, Geneticist Dolores Mornhinweg, Assistant Researcher Rita Veal, Biological Technician
Alternate Hosts	Stillwater, OK Dean Kindler, Research Entomologist Tim Springer, Agricultural Research Technician
Insect Genetics	Stillwater, OK Gary Puterka, Research Entomologist Columbia, MO Bill Steiner, Research Geneticist, Insects

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<u>Simulation Modeling</u>

<u>Stillwater, OK</u>
Norman Elliott, Research Biologist

<u>Biosystematics</u>

<u>Beltsville, MD</u>
Manya Stoetzel, Research Entomologist
Paul Marsh, Research Entomologist

<u>Biological Control</u>

<u>Stillwater, OK</u>
David Reed, Research Entomologist
Norman Elliott, Research Biologist
Brian Jones, Biological Technician

<u>Behoust, France</u>
Keith Hopper, Research Entomologist
Francis Gruber, Agricultural Assistant, Entomol.
Guy Mercadier, Pathology Technician
Eva Rey, Laboratory Technician

<u>Brookings, SD</u>
Robert Kieckhefer, Research Entomologist

<u>Newark, DE</u>
Roger Fuester, Research Entomologist
Lawrence Ertle, Entomologist
Paul Schaefer, Research Entomologist
Ken Swan, Biological Technician
Joseph Tropp, Biological Technician

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Steve Wraight, Research Entomologist

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